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Methods for microbiological and chemical determinations of essential amino acids in proteins and foods

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METHODS FOR MICROBIOLOGICAL AND CHEMICAL DETERMINATIONS OF ESSENTIAL AMINO ACIDS IN PROTEINS AND FOODS

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This publication condenses for easier reference results of research in the Bureau of Human Nutrition and Home Economics in the development of microbiological and chemical methods for the quantitative determination of the 10 so-called nutritionally essential amino acids. These methods have been applied to the analyses of some proteins and foods. Description of the methods and of the analytical results obtained has been published separately for each of the amino acids as work on each was completed. Here, data for all 10 are brought together under one cover.

Organisms Employed

Lactobacillus arabinosus 17–5 was employed for the determination of methionine; *Leuconostoc mesenteroides* P–60, for lysine, histidine, leucine, phenylalanine, and isoleucine; *Streptococcus faecalis* No. 9790, for arginine, threonine, and valine.[1] Tryptophane was assayed by a colorimetric method.

Inoculum

Stab stock cultures were carried in a medium having the following composition: 1 gm. glucose, 1 gm. Bacto yeast extract, and 1.5 gm. agar per 100 cc. The cultures were stored in a refrigerator and subcultured each month. Inoculum for the assay was prepared by transferring a small amount of the growth from a stab culture to a centrifuge tube containing 10 cc. of a medium consisting of 1 gm. of glucose, 1 gm. Bacto yeast extract, and 100 cc. of a liver infusion prepared as recommended by the Difco Laboratories. After incubation at 35° C. for 24 hours, the cells were centrifuged, washed with sterile 0.9 percent salt solution, and then suspended in 5 cc. of the same solution. One drop of this cell suspension was used to inoculate each tube in the assay.

[1] These micro-organisms were obtained from the American Type Culture Collection, Georgetown University School of Medicine, Washington, D. C.

Basal Medium

The composition of the standard basal medium shown in table 1 includes all of the carbohydrate, inorganic salts, vitamins, amino acids, and other substances essential for the growth of the bacteria. The amino acids are present in the proportion in which they occur in an acid hydrolysate of casein, with cystine and tryptophane added. When developing some of the standard curves in order that maximum titration values could be obtained, additional amounts of some of the amino acids were required. When using *L. mesenteroides* P-60, in the determination of lysine, histidine, leucine, isoleucine, and phenylalanine, 416 mg. per liter of L-arginine hydrochloride was used instead of the 96 mg. shown in the table; for the determination of phenylalanine, in addition to the change in arginine, the amount of tyrosine was increased from 130 mg. to 390 mg. No change in the basal medium was required when using *S. faecalis* for the determination of arginine, threonine, or valine.

Preparation of Standard Curves

Typical standard curves are shown in figures 1 and 2. Careful attention was given to the purity of the standard amino acids used in preparing these standard curves. Points on these curves were then tested by checking for any change in titration values by adding 1.2 mg. of each amino acid in excess of that present in the basal media.

Preparation of Samples for Assay

An amount of material equivalent to 1 gm. of protein was refluxed for 24 hours with 25 cc. of 20-percent hydrochloric acid. The hydrolysate was concentrated to a small volume in an air bath, and the residue made up to a volume of 100 cc. with distilled water. For assays, appropriate aliquots were taken, the solution adjusted to pH 6.8 and made up to a volume of 1 liter. Solutions obtained in this way with protein equivalents of 100 γ per cc. were stored under toluene in the refrigerator.

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Assay Procedure

For the amino acid assays, 5-cc. quantities of the basal medium were used. The material to be assayed was added, and the volume brought to 10 cc. by addition of distilled water. The tubes were autoclaved at 15 pounds pressure for 15 minutes, cooled, inoculated with one drop of the inoculum, and incubated at 35° to 36° C. for 72 hours. The lactic acid was titrated with standard NaOH using bromothymol blue as indicator. Each material was determined in triplicate at four different levels, and the average results were taken. Many of the results are the averages of two or more determinations on the same sample.

The results given in table 2 are those obtained in the laboratory of the Bureau of Human Nutrition and Home Economics and those obtained on the same materials by other workers using both microbiological and chemical methods.

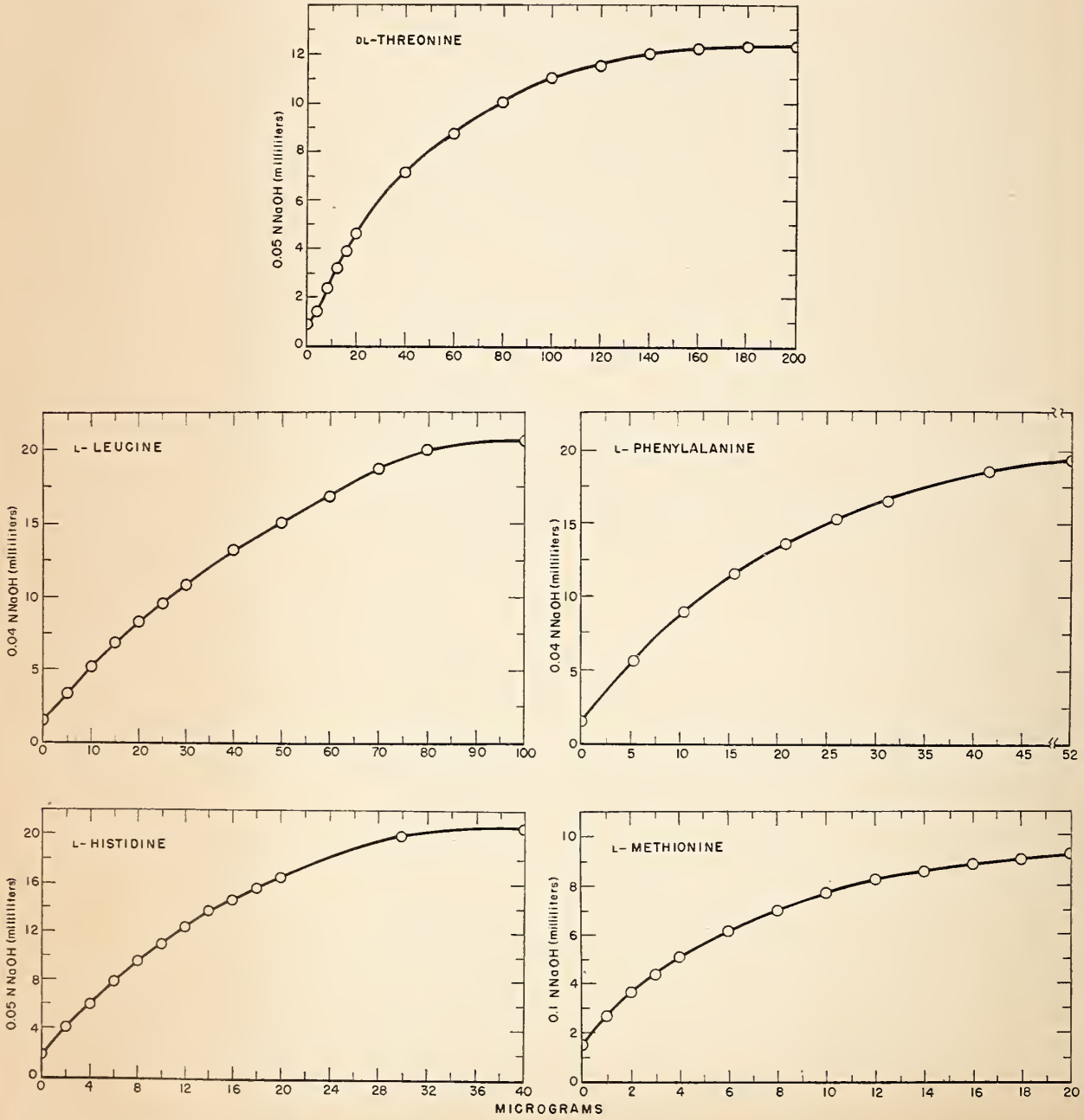

FIGURE 1.—Typical standard curve for DL-Threonine, L-Leucine, L-Phenylalanine, L-Histidine, L-Methionine.

TABLE 1.—*Composition of basal medium for assay of amino acids*

Nutrient	Amount	Nutrient	Amount	Nutrient	Amount
Glucose	20 gm.	Pyridoxamine dihydrochloride	.4 mg.	L-Hydroxyproline	20 mg.
Sodium acetate (anhydrous)	12 gm.	Calcium pantothenate	.4 mg.	DL-Isoleucine	50 mg.
Salts A:		Riboflavin	.4 mg.	DL-Leucine	400 mg.
K_2HPO_4	1 gm.	Nicotinic acid	.8 mg.	DL-Lysine hydrochloride	300 mg.
KH_2PO_4	1 gm.	*p*-Aminobenzoic acid	.4 mg.	DL-Methionine	200 mg.
Salts B:		Biotin	.01 mg.	DL-Norleucine	400 mg.
$MgSO_47H_2O$	400 mg.	Folic acid	.002 mg.	DL-Phenylalanine	160 mg.
$MnSO_44H_2O$	20 mg.	DL-Alanine	80 mg.	L-Proline	140 mg.
NaCl	20 mg.	L-Arginine hydrochloride	96 mg.	DL-Serine	240 mg.
$FeSO_47H_2O$	20 mg.	DL-Aspartic acid	240 mg.	DL-Threonine	180 mg.
Adenine	100 mg.	L-Cystine	400 mg.	DL-Tryptophane	400 mg.
Guanine	100 mg.	DL-Glutamic acid + H_2O	940 mg.	L-Tyrosine	130 mg.
Uracil	100 mg.	Glycine	400 mg.	DL-Valine	240 mg.
Thiamine chloride	2.0 mg.	L-Histidine hydrochloride + H_2O	54 mg.		

Solution brought to 1,000 cc. volume, pH 6.8.

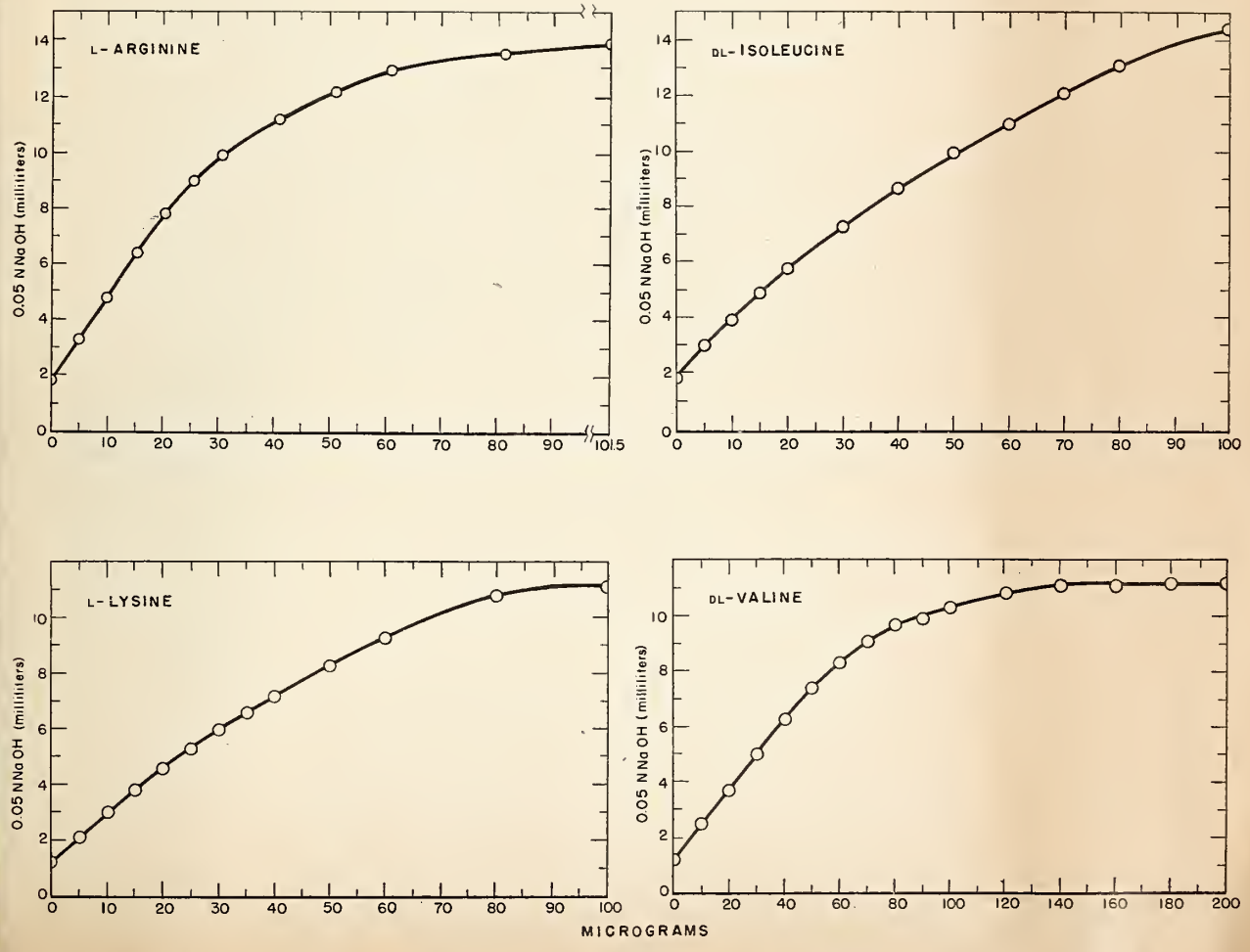

FIGURE 2.—Typical standard curve for L–Arginine, DL–Isoleucine, L–Lysine, DL–Valine.

TABLE 2.—*Content of essential amino acids in some proteins and foods (percentages)*[1]

Material (*55*)[2]	N	Arginine		Histidine		Isoleucine		Leucine		Lysine	
		Value (*61*) this laboratory	Other values	Value (*60*) this laboratory	Other values	Value (*64*) this laboratory	Other values	Value (*63*) this laboratory	Other values	Value (*58*) this laboratory	Other values
PROTEINS											
Arachin	18. 30	13. 50	13. 94(*95*) 15. 4 (*18*)	2. 16	2. 16(*18*) 2. 31(*96*)	4. 55	----	7. 61	----	2. 72	1. 83(*65*) 2–4 (*18*) 4. 5 (*18*)
Casein	16. 07	3. 81	3. 6 (*50*) 3. 6 (*51*) 3. 6 (*4*) 3. 7 (*76*) 3. 7 (*45*) 3. 7 (*16*) 3. 72(*95*) 3. 9 (*93*) 4. 3 (*18*)	2. 65	2. 53(*96*) 2. 6 (*50*) 2. 6 (*51*) 2. 8 (*93*) 3. 0 (*36*) 3. 1 (*34*) 3. 2 (*45*) 4. 1 (*10*)	5. 63	5. 2 (*97*) 5. 6 (*93*) 6. 0 (*50*) 6. 4 (*51*) 7. 6 (*48*) 8. 0 (*10*)	9. 22	8. 1 (*47*) 9. 1 (*21*) 9. 4 (*29*) 9. 5 (*50*) 9. 6 (*88*) 9. 8 (*87*) 9. 8 (*23*) 9. 9 (*93*) 9. 9 (*51*) 10. 8 (*10*) 11. 1 (*53*) 12. 1 (*18*) 14. 4 (*97*)	8. 20	5. 4 (*1*) 6–8 (*12*) 7. 6 (*50*) 7. 6 (*45*) 7. 7 (*80*) 7. 7 (*93*) 8. 1 (*99*) 8. 3 (*51*) 8. 3 (*33*) 8. 7 (*30*)
Coconut globulin	17. 42	16. 73	15. 92(*66*)	1. 52	2. 42(*66*)	4. 43	----	7. 18	5. 96(*66*)	4. 37	----
Conarachin	18. 20	16. 53	12. 7 (*18*)	2. 05	----	3. 98	----	6. 61	----	4. 69	7. 0 (*18*)
Cottonseed globulin	18. 00	14. 72	13. 6 (*39*) 14. 92(*95*)	3. 38	2. 9 (*39*)	4. 62	2. 2 (*18*) 2. 5 (*39*)	7. 06	6. 8 (*23*) 8. 4 (*39*)	4. 15	2. 25(*83*) 4. 90(*39*)
Edestin	18. 55	16. 51	14. 0 (*18*) 16. 7 (*90*) 16. 76(*95*)	2. 50	2. 52(*96*) 2. 62(*90*) 2. 8 (*18*)	5. 54	4. 7 (*91*) 6. 47(*48*)	7. 50	5. 5 (*47*) 7. 0 (*18*) 7. 4 (*23*) 7. 4 (*92*)	3. 23	2. 32(*18*) 3. 90(*94*)
Gelatin (Bacto)	18. 32	9. 11	8. 0 (*50*) 8. 68(*95*) 9. 08(*16*) 9. 1 (*93*) 9. 30(*76*)	. 77	. 58(*93*) . 79(*50*) . 83(*45*) . 9 (*18*) 1. 0 (*10*)	1. 25	1. 5 (*50*) 1. 7 (*18*) 1. 72(*93*) 1. 9 (*10*)	3. 30	2. 7 (*53*) 3. 2 (*50*) 3. 2 (*10*) 3. 3 (*29*) 3. 5 (*93*) 3. 5 (*79*) 3. 6 (*23*)	4. 44	4. 1 (*50*) 5. 04(*18*) 5. 8 (*93*) 6. 9 (*31*)
Glycinin	17. 30	7. 94	8. 5 (*18*)	1. 97	2. 08(*96*)	5. 69	----	8. 07	8. 4 (*23*)	6. 90	----
Lactalbumin	15. 39	3. 42	3. 2 (*50*) 3. 4 (*16*)	1. 50	1. 7 (*18*) 1. 8 (*50*)	6. 12	6. 0 (*50*)	12. 90	10. 8 (*50*) 10. 8 (*21*)	10. 80	8. 4 (*50*) 9. 6 (*18*) 9. 87(*84*)
Ovalbumin (crystalline)	15. 98	6. 03	5. 66(*95*) 5. 7 (*45*) 5. 94(*93*) 6. 0 (*16*) 6. 6 (*76*)	2. 06	2. 1 (*18*) 2. 3 (*93*) 2. 4 (*45*)	7. 41	7. 0 (*93*)	9. 43	9. 1 (*79*) 9. 2 (*93*) 9. 6 (*23*)	6. 32	5. 0 (*18*) 6. 0 (*45*) 6. 3 (*31*) 6. 6 (*93*)
Ox muscle protein	16. 00	7. 87	6. 0 (*50*) 6. 3 (*18*) 6. 9 (*13*)	1. 98	1. 9 (*18*) 2. 25(*13*) 3. 5 (*50*)	6. 50	5. 3 (*50*) 5. 7 (*38*)	9. 37	7. 7 (*50*)	10. 00	7. 9 (*50*) 8. 1 (*13*)
Peanut, total globulins	18. 01	14. 16	----	1. 65	----	4. 28	----	7. 45	8. 1 (*23*)	3. 50	----
Phaseolin (navy bean)	16. 07	5. 97	----	2. 24	----	6. 69	----	10. 50	----	7. 20	----
Wheat bran globulin	17. 76	13. 30	----	1. 86	----	3. 82	----	6. 35	----	4. 15	----
Zein	16. 00	1. 95	1. 60(*95*) 1. 80(*18*)	. 76	. 7 (*18*) . 85(*96*)	5. 03	----	21. 10	15. 4 (*23*) 23. 7 (*18*)	. 21	0 (*18*) . 06(*99*)

See footnotes at end of table.

TABLE 2.—*Content of essential amino acids in some proteins and foods (percentages)* [1]—Continued

Material (*55*) [2]	N	Methionine		Phenylalanine		Threonine		Tryptophane		Valine	
		Value (*56*) this laboratory	Other values	Value (*62*) this laboratory	Other values	Value (*59*) this laboratory	Other values	Value (*54*) this laboratory	Other values	Value (*57*) this laboratory	Other values
PROTEINS											
Arachin	18. 30	0. 24	0. 54(*5*) . 57(*14*) . 67(*24*) . 77(*15*)	6. 96	5. 03(*25*) 5. 5 (*18*)	2. 89	2. 65(*24*)	0. 90	0. 6 (*18*) . 68 (*26*) 1. 08 (*98*)	4. 85	----
Casein	16. 07	2. 58	2. 6 (*93*) 2. 85(*73*) 2. 94– 3. 64(*75*) 3. 12(*14*) 3. 50(*7*) 3. 50(*17*)	4. 89	3. 7 (*47*) 3. 99(*25*) 4. 77(*2*) 4. 9 (*35*) 5. 1 (*10*) 5. 2 (*51*) 5. 3 (*50*) 5. 45(*48*) 5. 5 (*97*) 5. 71(*49*) 5. 9 (*93*)	4. 80	4. 0 (*81*) 4. 2 (*93*) 4. 42(*37*) 4. 6 (*97*) 4. 65(*10*)	1. 20	1. 0 (*10*) 1. 07 (*93*) 1. 2 (*51*) 1. 20 (*98*) 1. 21 (*42*) 1. 26 (*48*) 1. 27 (*86*) 1. 54 (*44*) 1. 56 (*46*)	6. 90	5. 2 (*47*) 6. 2 (*88*) 6. 7 (*76*) 6. 91(*45*) 7. 0 (*40*) 7. 0 (*74*) 7. 1 (*50*) 7. 8 (*10*)
Coconut globulin	17. 42	2. 02	2. 05(*6*)	5. 10	2. 05(*66*)	4. 06	----	[3]. 66	----	5. 92	3. 57(*66*)
Conarachin	18. 20	2. 13	2. 12(*24*)	4. 32	3. 29(*25*)	1. 93	2. 02(*24*)	[3] 1. 20	. 91 (*26*)	3. 68	----
Cottonseed globulin	18. 00	1. 40	1. 7– 3. 2 (*39*)	8. 13	9. 1 (*39*)	3. 96	2. 9 (*39*)	1. 29	1. 5 (*18*) 1. 5 (*39*)	6. 05	7. 5 (*39*)
Edestin	18. 55	2. 12	2. 07(*6*) 2. 1 (*75*) 2. 3 (*14*) 2. 3 (*9*) 2. 52(*11*)	5. 43	4. 2 (*47*) 5. 22(*48*) 5. 45(*92*)	4. 34	----	[3] 1. 31	. 86 (*48*) 1. 28 (*92*) 1. 4 (*18*)	6. 39	4. 7 (*47*) 5. 1 (*40*) 6. 63(*92*)
Gelatin (Bacto)	18. 32	. 78	. 59(*93*) . 81(*14*) . 97(*6*)	2. 33	1. 57(*25*) 2. 2 (*50*) 2. 24(*2*) 2. 3 (*93*) 2. 45(*49*)	2. 10	1. 4 (*89*) 1. 9 (*50*) 1. 9 (*10*) 2. 0 (*93*) 2. 0 (*77*)	[3]. 044	0 (*18*) 0 (*3*) . 003(*42*) . 021(*93*)	2. 90	2. 5 (*50*) 2. 6 (*45*) 2. 7 (*76*) 2. 7 (*93*) 2. 7 (*10*)
Glycinin	17. 30	1. 15	1. 84(*5*)	5. 82	----	3. 00	----	[3] 1. 05	1. 04 (*42*) 1. 6 (*18*)	4. 56	----
Lactalbumin	15. 39	1. 62	2. 4 (*73*) 2. 62(*7*) 2. 80(*67*) 2. 98(*14*)	3. 59	2. 88(*2*) 3. 63(*25*) 3. 7 (*50*) 5. 6 (*18*)	5. 37	5. 0 (*43*) 5. 20(*18*) 5. 24(*81*) 5. 6 (*50*)	1. 72	1. 79 (*98*) 2. 20 (*21*) 2. 3 (*18*) 2. 35 (*41*) 2. 77 (*44*) 2. 8 (*3*)	5. 82	5. 9 (*50*)
Ovalbumin (crystalline)	15. 98	4. 43	3. 76– 4. 58(*73*) 4. 1 (*93*) 5. 10(*7*) 5. 22(*67*)	7. 17	6. 0 (*18*) 6. 18(*49*) 7. 9 (*93*)	4. 48	3. 6 (*93*)	[3] 1. 30	1. 29 (*41*) 1. 39 (*46*) 1. 41 (*93*) 1. 46 (*42*)	7. 54	6. 8 (*76*) 7. 0 (*93*) 7. 36(*45*)
Ox muscle protein	16. 00	2. 75	3. 17(*13*) 3. 21(*14*) 3. 3 (*17*) 3. 66(*5*)	4. 58	3. 9 (*50*) 4. 5 (*18*) 4. 92(*13*)	5. 80	4. 6 (*13*) 5. 4 (*50*) 5. 7 (*18*)	1. 30	1. 17 (*98*) 1. 21 (*72*) 1. 26 (*41*)	5. 85	5. 2 (*50*) 5. 2 (*38*)
Peanut, total globulins	18. 01	1. 00	----	5. 75	----	3. 24	----	[3]. 92	. 79 (*26*)	5. 00	----
Phaseolin (navy bean)	16. 07	1. 12	----	8. 04	----	4. 16	----	. 50	. 38 (*98*)	6. 00	----
Wheat bran globulin	17. 76	1. 04	----	4. 22	----	3. 50	----	[3]. 86	1. 0 (*69*)	6. 56	----
Zein	16. 00	1. 41	1. 68(*73*) 2. 32(*8*)	7. 30	6. 77(*49*) 7. 1. (*18*)	2. 62	2. 3 (*77*) 2. 5 (*22*)	[3]. 026	. 1 (*42*) . 10 (*18*)	3. 98	3. 3 (*18*)

See footnotes at end of table.

TABLE 2.—*Content of essential amino acids in some proteins and foods (percentages)*[1]—Continued

Material (55)[2]	N	Arginine		Histidine		Isoleucine		Leucine		Lysine	
		Value (61) this laboratory	Other values	Value (60) this laboratory	Other values	Value (64) this laboratory	Other values	Value (63) this laboratory	Other values	Value (58) this laboratory	Other values
FOODS											
Barley, pearled	1.86	0.53	0.32(10)	0.21	0.19(10)	0.53	0.45(10)	0.89	0.64(10)	0.28	0.26(10)
Brazil nut meal	9.03	7.62	———	1.08	———	2.09	———	4.09	———	1.80	———
Corn germ, defatted	3.93	2.18	1.67(18) 2.48(38)	.67	.71(18)	.92	1.0 (38)	1.83	1.65(53) 1.89(38)	1.45	1.41(18)
Corn, whole, yellow	2.22	.65	.46(32) .56(18) .59(10)	.31	.29(32) .33(18) .44(10)	.61	.89(10)	1.99	2.07(10) 2.98(18)	.32	.14(27) .35(18) .40(18) .44(10)
Cottonseed flour	10.36	7.72	4.79(18) 4.87(10) 8.55(38)	1.62	1.68(18) 1.78(10)	2.16	2.20(70) 2.52(38) 2.91(10)	3.81	3.24(18) 3.24(70) 3.56(10) 3.88(38)	2.92	1.76(18) 2.42(10)
Egg, whole, dried	8.11	4.82	3.24(78)	1.17	———	4.43	3.57(38) 4.05(78)	6.37	4.66(78)	4.00	3.04(18)
Milk, dry skim	6.57	1.15	1.24(10) 1.31(51) 1.48(93)	1.01	.92(52) .99(93) .99(51) 1.33(10)	2.51	2.14(93) 2.38(52) 2.46(51) 2.96(20) 2.96(10)	4.24	3.57(20) 3.78(10) 3.96(52) 4.07(93) 4.35(51) 4.64(53)	2.91	2.90(10) 3.11(18) 3.41(51) 3.57(93)
Oatmeal	2.73	1.26	.70(10) 1.02(18)	.38	.34(18) .41(10)	.76	.71(10) .90(18)	1.32	1.12(10) 1.37(18)	.51	.22(28) .57(18)
Peanut flour	10.15	7.76	6.29(18) 8.75(38)	1.34	1.33(18)	2.44	2.16(70) 2.92(38)	4.25	3.49(18) 3.49(70) 4.25(38)	1.92	1.91(18) 1.93(18)
Peas, blackeyed	4.15	1.95	———	.75	———	1.27	1.32(18)	2.06	———	1.70	———
Rice, white	1.26	.69	.57(18)	.18	.12(18)	.35	———	.68	.61(18)	.22	.24(68) .34(68)
Rye, whole	1.98	.67	.53(93)	.27	.22(93)	.51	.50(93)	.83	.77(93)	.41	.41(10) .51(93)
Soybean flour	8.85	4.33	2.92(10) 3.93(93) 4.15(85)	1.32	1.27(93) 1.55(85) 1.65(10)	2.71	2.49(93) 2.60(70) 2.80(85) 3.39(10)	4.16	3.65(18) 3.65(70) 4.09(93) 4.10(53) 4.19(85) 4.20(38) 4.36(10)	3.97	3.01(18) 3.01(93) 3.72(10) 3.72(99)
Wheat germ, defatted	6.50	2.80	2.44(18) 3.90(38)	.84	1.0 (18)	1.46	1.42(18) 1.54(38)	2.44	2.03(53) 2.68(38) 3.01(18)	2.52	1.13(82) 2.24(18)
Wheat, whole	3.07	.86	.59(10) .63(18) .81(93)	.39	.38(93) .46(10)	.69	.63(70) .69(93) .83(10)	1.13	1.11(18) 1.11(70) 1.18(10) 1.30(93)	.48	.47(10) .51(18) .54(93)
Yeast, dried, brewer's	7.71	2.26	2.08(19) 2.17(93)	.78	1.0 (93) 1.38(19)	2.37	2.02(93) 2.84(19) 2.90(38)	3.25	2.92(53) 3.42(93) 3.56(19)	3.50	3.08(18) 3.08(93)

See footnotes at end of table.

TABLE 2.—*Content of essential amino acids in some proteins and foods (percentages)* [1]—Continued

Material (*55*) [2]	N	Methionine		Phenylalanine		Threonine		Tryptophane		Valine	
		Value (*56*) this laboratory	Other values	Value (*62*) this laboratory	Other values	Value (*59*) this laboratory	Other values	Value (*54*) this laboratory	Other values	Value (*57*) this laboratory	Other values
FOODS											
Barley, pearled	1. 86	0. 12	0. 13(*10*)	0. 68	0. 45(*10*)	0. 42	0. 26(*10*)	[3] 0. 13	0. 09 (*69*) . 13 (*10*)	0. 60	0. 45(*10*)
Brazil nut meal	9. 03	2. 78	———	2. 06	———	1. 60	———	[3]. 74	———	2. 70	———
Corn germ, defatted	3. 93	. 35	. 57(*18*)	. 96	. 71(*38*) 1. 37(*18*)	1. 09	1. 16(*18*)	. 23	. 24 (*98*) . 32 (*18*) . 88 (*38*)	1. 39	1. 43(*18*) 1. 45(*38*)
Corn, whole, yellow	2. 22	. 20	. 30(*10*)	. 73	. 62(*18*) . 74(*10*)	. 54	. 44(*10*) . 47(*18*) . 64(*43*)	[3]. 066	. 07 (*10*) . 07 (*69*) . 09 (*18*) . 12 (*42*)	. 74	. 74(*18*) . 74(*10*)
Cottonseed flour	10. 36	. 85	. 81(*10*) 1. 04(*18*)	3. 40	2. 69(*38*) 3. 56(*10*) 4. 4 (*18*)	2. 38	1. 78(*10*) 1. 95(*18*)	. 70	. 58 (*69*) . 63 (*98*) . 65 (*10*) . 84 (*18*) . 92 (*71*) . 97 (*71*) 2. 49 (*38*)	2. 91	2. 39(*70*) 2. 91(*10*) 3. 30(*38*)
Egg, whole, dried	8. 11	1. 39	———	3. 71	3. 0 (*18*) 3. 09(*38*) 3. 24(*78*)	3. 00	2. 51(*18*)	[3]. 87	. 83 (*38*)	3. 55	2. 54(*18*)
Milk, dry skim	6. 57	. 89	. 87(*93*) . 87(*51*) . 93(*10*)	1. 82	1. 89(*51*) 2. 05(*10*) 2. 18(*93*) 2. 25(*52*) 2. 36(*18*)	2. 15	1. 64(*93*) 1. 89(*18*) 1. 97(*51*) 2. 01(*97*)	[3]. 46	. 41 (*10*) . 54 (*93*) . 54 (*42*) . 58 (*51*)	2. 84	2. 50(*51*) 2. 50(*10*) 2. 71(*93*)
Oatmeal	2. 73	. 18	. 20(*10*) . 39(*18*)	. 79	. 82(*10*) 1. 18(*18*)	. 62	. 61(*18*)	[3]. 18	. 14 (*10*) . 22 (*18*) . 25 (*42*)	. 90	. 71(*10*)
Peanut flour	10. 15	. 52	. 57(*18*)	3. 33	1. 79(*38*) 3. 43(*18*)	1. 93	. 95(*18*)	. 56	. 45 (*69*) . 55 (*98*) . 63 (*18*) . 71 (*71*) 1. 24 (*38*)	2. 83	2. 54(*18*) 2. 54(*70*) 3. 34(*38*)
Peas, blackeyed	4. 15	. 25	———	1. 34	———	1. 09	———	. 23	. 24 (*98*)	1. 41	———
Rice, white	1. 26	. 11	. 27(*18*)	. 38	. 49(*18*)	. 28	. 31(*18*)	[3]. 069	. 09 (*42*) . 10 (*18*)	. 50	. 50(*18*)
Rye, whole	1. 98	. 14	. 15(*93*) . 29(*18*)	. 56	. 69(*93*)	. 49	. 27(*10*) . 38(*93*)	[3]. 095	. 068(*10*) . 16 (*93*)	. 62	. 62(*93*)
Soybean flour	8. 85	. 55	———	2. 63	2. 71(*10*) 2. 84(*38*) 2. 93(*93*) 2. 93(*85*) 3. 1 (*18*)	2. 53	2. 16(*93*) 2. 16(*43*) 2. 20(*18*) 2. 57(*10*)	. 62	. 53 (*69*) . 55 (*98*) . 58 (*10*) . 60 (*38*) . 66 (*93*) . 66 (*42*) . 89 (*18*)	2. 72	2. 32(*70*) 2. 57(*93*) 2. 92(*10*) 2. 92(*85*) 2. 98(*38*)
Wheat germ, defatted	6. 50	. 51	. 81(*18*)	1. 41	1. 66(*38*) 1. 7 (*18*)	1. 63	1. 55(*18*)	. 30	. 36 (*98*) . 41 (*18*) 1. 18 (*38*)	1. 96	2. 08(*18*) 2. 60(*38*)
Wheat, whole	3. 07	. 19	. 23(*93*) . 23(*10*)	. 78	. 81(*10*) . 96(*93*) 1. 07(*18*)	. 57	. 48(*10*) . 49(*93*) . 63(*18*)	. 16	. 13 (*98*) . 17 (*69*) . 19 (*18*) . 22 (*42*) . 24 (*10*) . 26 (*93*)	. 79	. 68(*70*) . 83(*10*) . 86(*93*)
Yeast, dried, brewer's	7. 71	. 53	. 66(*93*) . 96(*18*)	1. 79	1. 73(*38*) 1. 97(*19*) 2. 12(*93*)	2. 54	2. 41(*18*) 2. 46(*93*)	[3]. 45	. 48 (*69*) . 51 (*93*) . 64 (*42*) . 79 (*38*)	2. 54	2. 41(*19*) 2. 55(*18*) 2. 60(*93*) 3. 08(*38*)

[1] Calculated on moisture-ash-free basis. [2] Italic numbers in parentheses refer to Literature Cited, page 8. [3] Unpublished results.

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